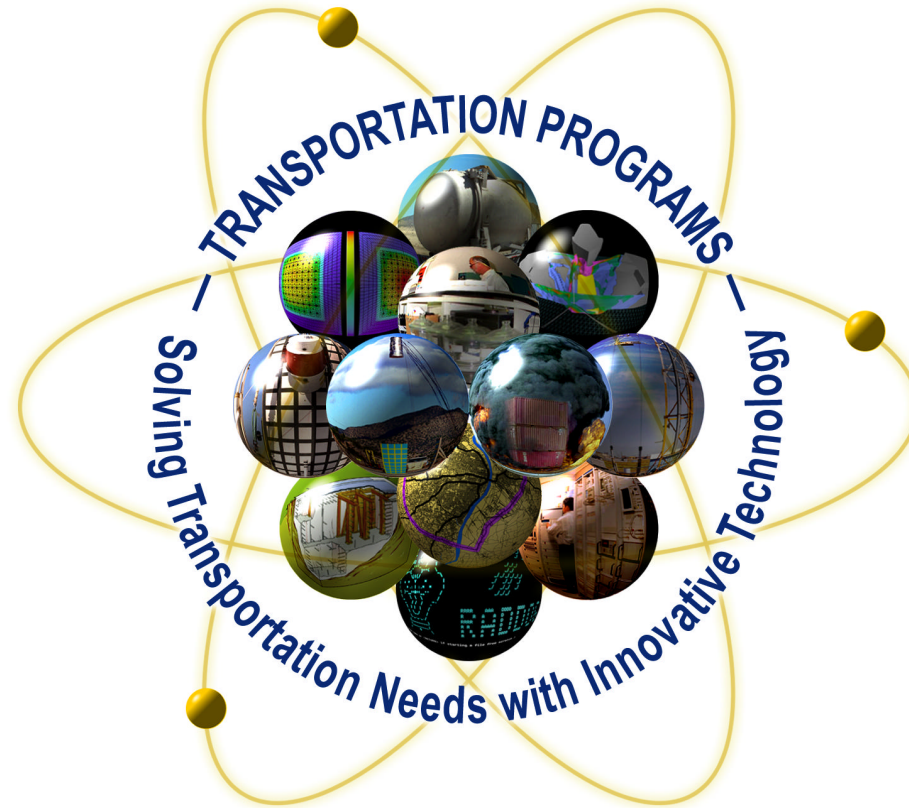


www.sandia.gov/tp/tp.htm

Use of Inelastic Analysis in Cask Design



Douglas J. Ammerman

Nicole L. Breivik

Transportation Programs at Sandia National Laboratories



Advantages of Inelastic Analysis determined by Comparative Analyses

Elastic analysis may underpredict maximum stress at a particular location.

- **Redistribution of forces occurs after yielding**
- **In the calculations, the maximum stress in the inner shell was lower for elastic analysis.**

Elastic analysis may overpredict the maximum stress.

- **The stress at the location of peak stress is always higher for elastic analysis, sometimes leading to grossly overdesigned packages.**



U.S. Department of Energy
National Transportation Program





Disadvantages of Inelastic Analysis

- **A more detailed description of the material behavior is needed.**
- **Complete stress history of the cask is needed.**
- **Analysis acceptance criteria are needed.**



U.S. Department of Energy
National Transportation Program





Inelastic Analysis of Puncture Event

- **Sandia has performed a series of tests and analyses to determine the response of packages to the puncture event.**
- **The results of this work creates confidence in the ability of inelastic analysis to determine package response to these accidents.**



U.S. Department of Energy
National Transportation Program





0.3125" Carbon Steel Shell backed by Lead

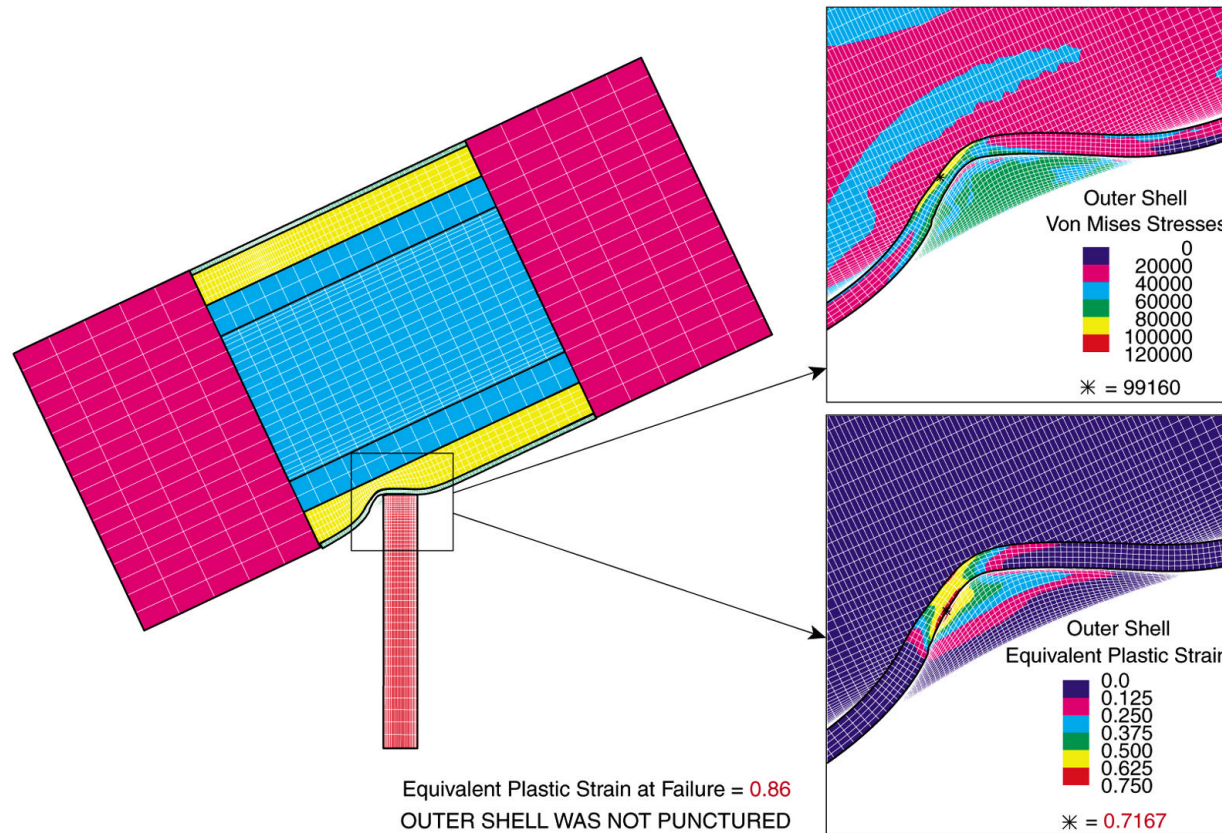


U.S. Department of Energy
National Transportation Program





0.3125" Carbon Steel Shell backed by Lead

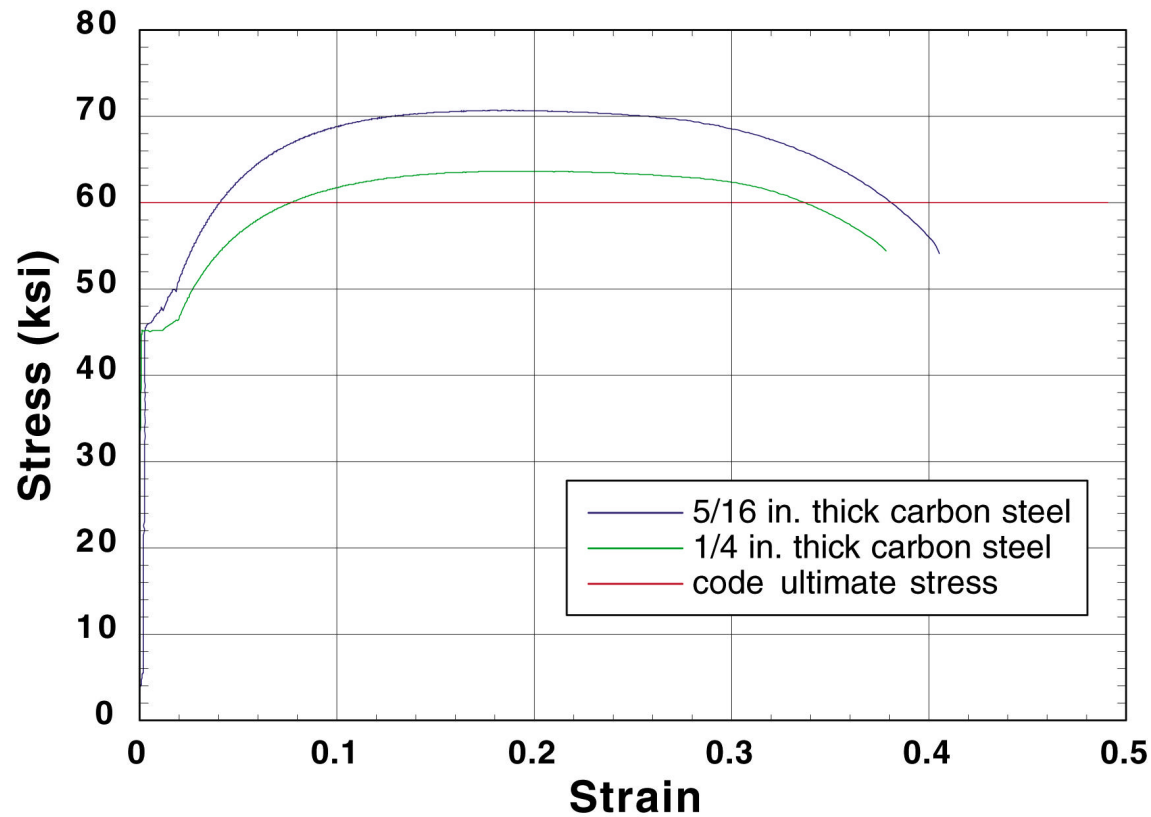


U.S. Department of Energy
National Transportation Program





Stress Strain Curves for the Carbon Steel used in Tests



U.S. Department of Energy
National Transportation Program

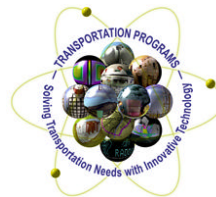




0.25" Carbon Steel Shell backed by Lead



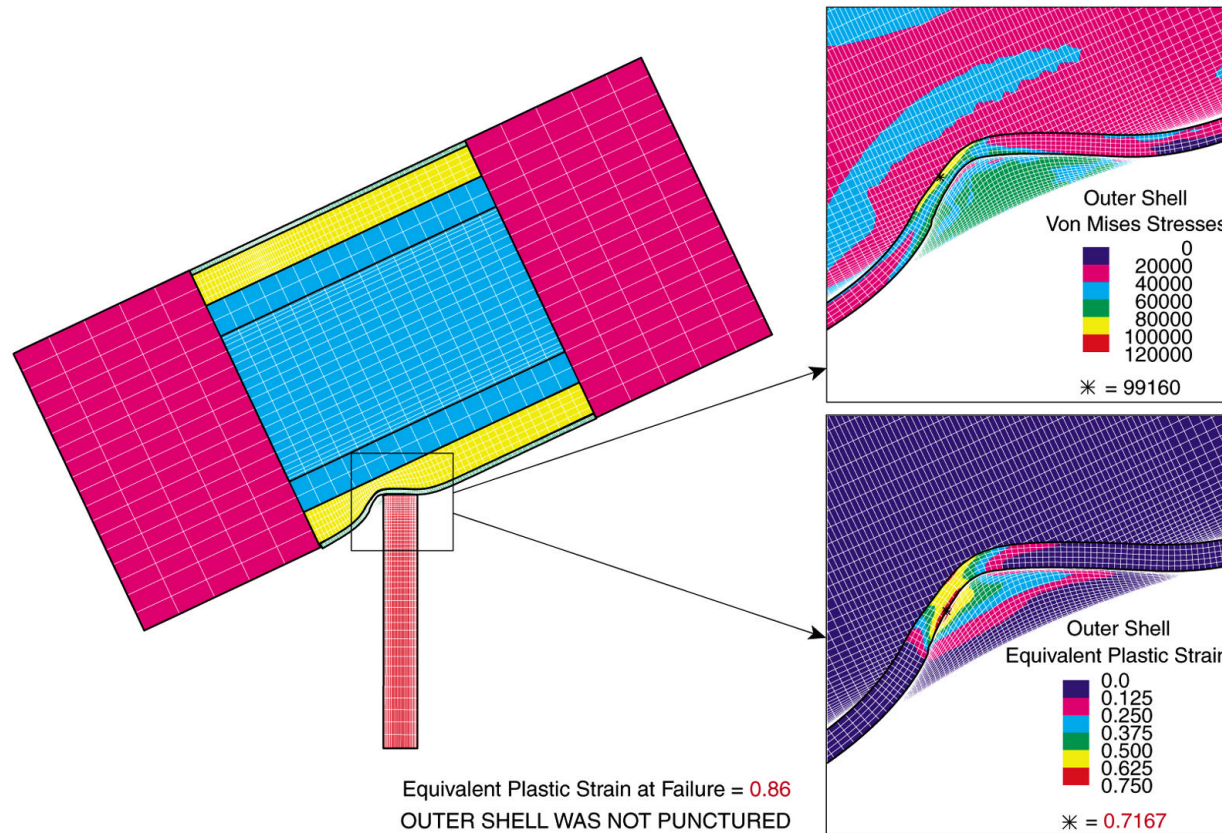
U.S. Department of Energy
National Transportation Program



Sandia
National
Laboratories



0.25" Carbon Steel Shell backed by Lead



U.S. Department of Energy
National Transportation Program





Application of Results to Cask Design

- **Structural cask design is governed by the ASME Boiler and Pressure Vessel Code, Section III, Division 3 (NUPACK code).**
- **This code gives an empirical formula for determining the shell thickness necessary to prevent puncture.**
- **Code Case N-626 to this code allows inelastic analysis for calculating the stress in the inner shell.**



U.S. Department of Energy
National Transportation Program





Design of a Steel-Lead-Steel Walled Cask

- **The National Spent Nuclear Fuel Program has developed a conceptual design for a cask to transport DOE spent fuel.**
- **This cask has an estimated weight of 135 tons, 6 inches of lead shielding, and an inner diameter of 72 inches.**
- **This cask was used as an example to apply inelastic analysis for design against puncture.**

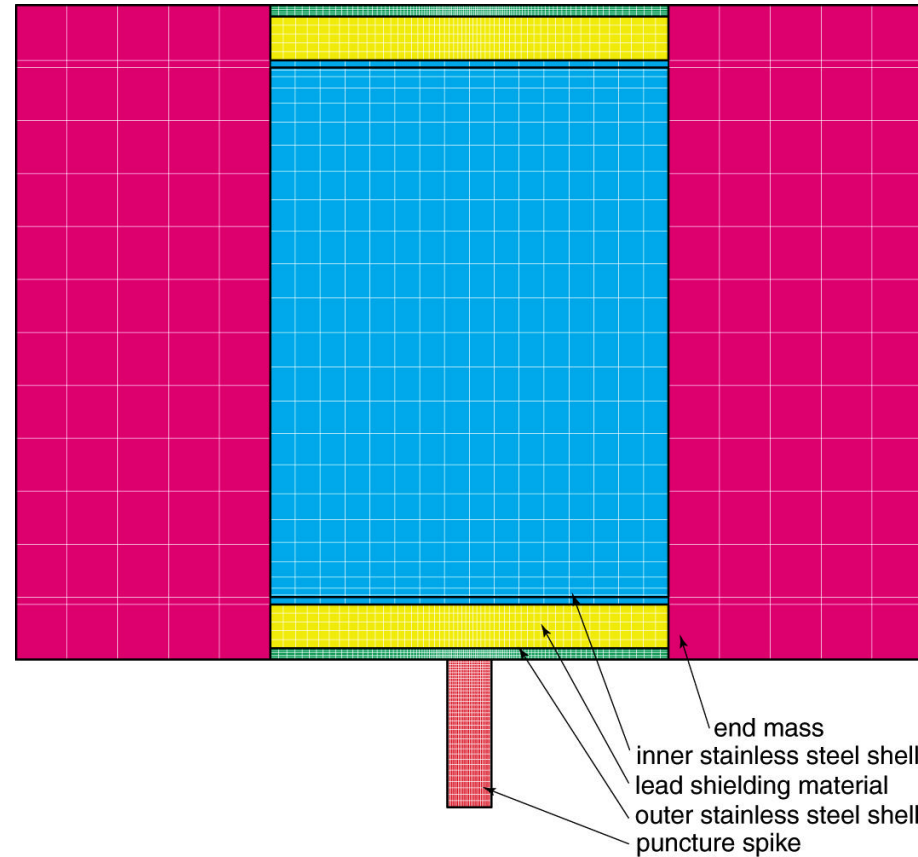


U.S. Department of Energy
National Transportation Program





Initial Finite Element Mesh

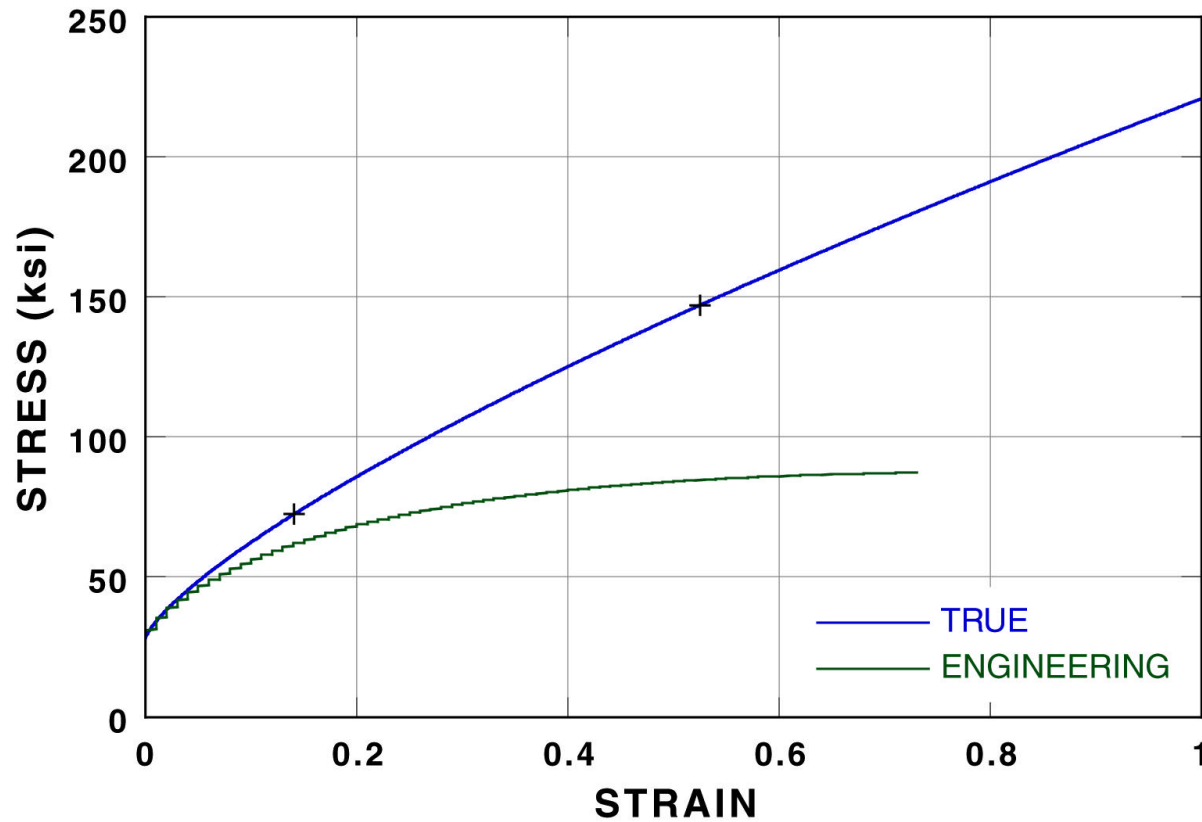


U.S. Department of Energy
National Transportation Program





True Stress vs. True Strain Curve for 304L Stainless Steel

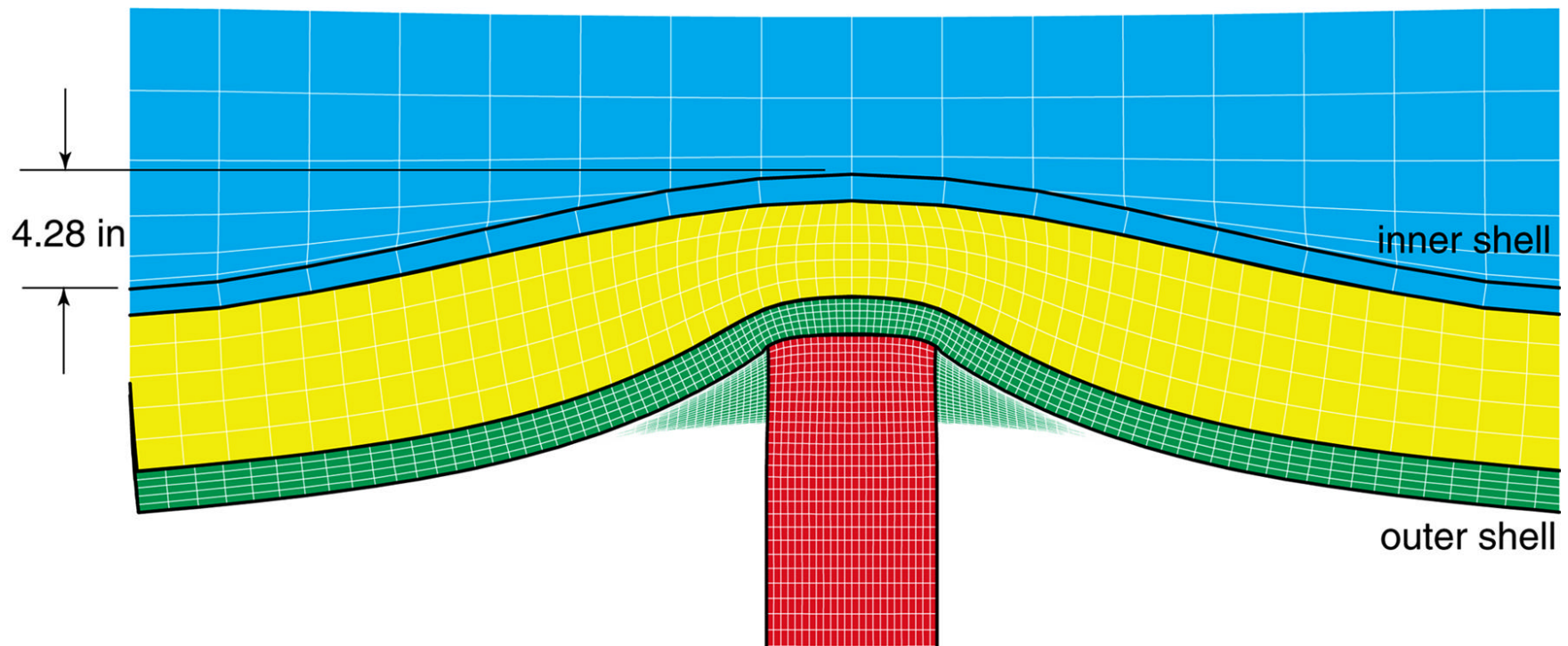


U.S. Department of Energy
National Transportation Program





Deflection of Interior Containment Boundary for Outer Shell = 1.54 inches

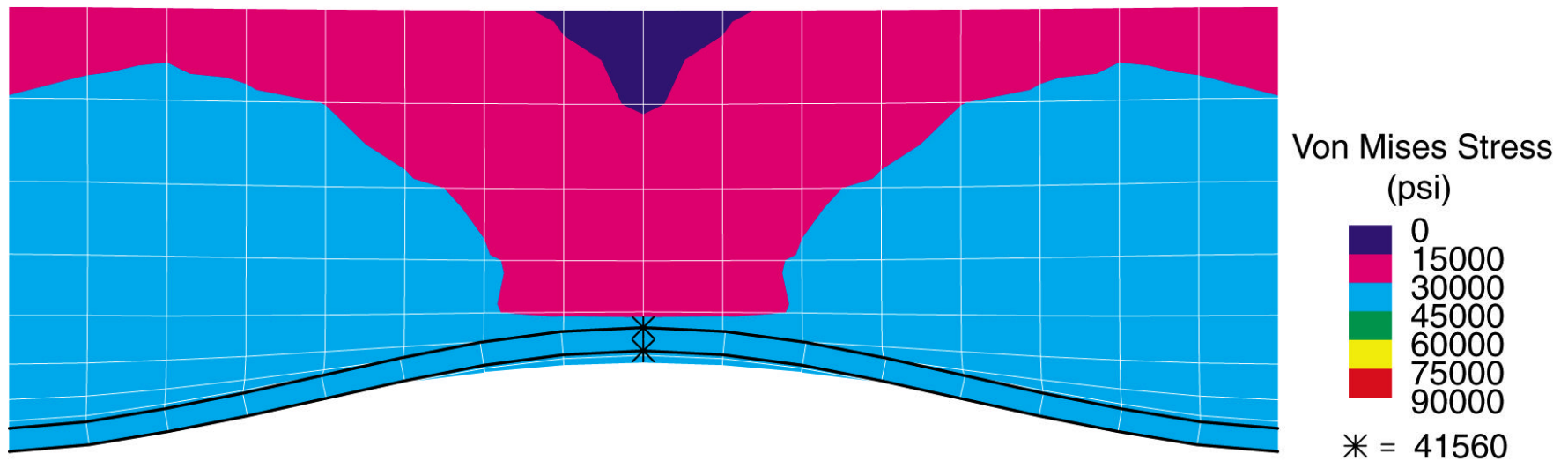


U.S. Department of Energy
National Transportation Program





Von Mises Stress in Inner Shell for Outer Shell Thickness = 1.54 inches

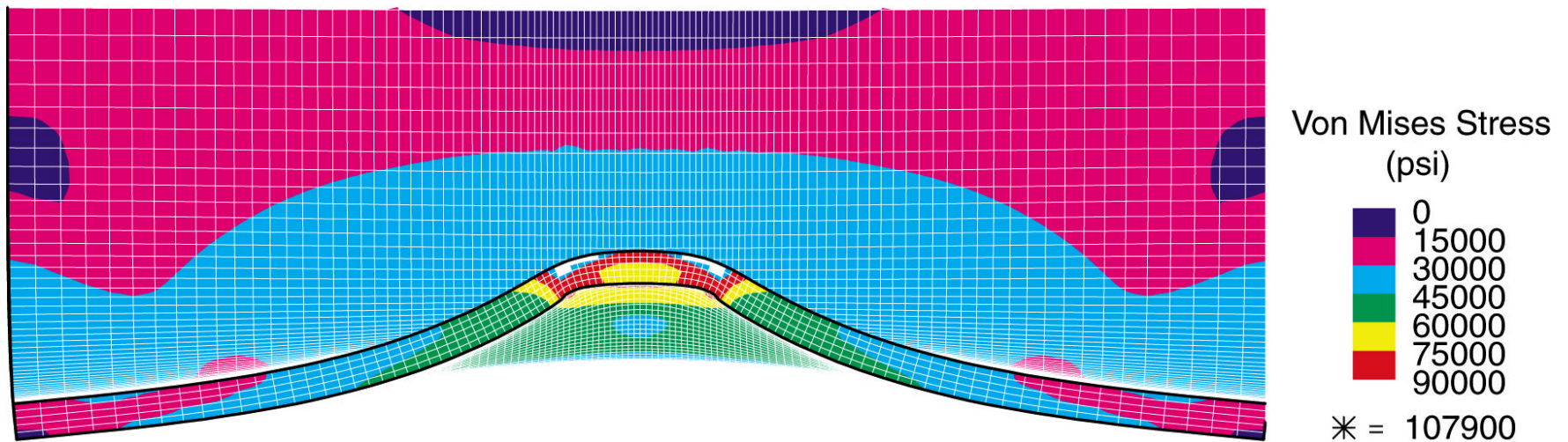


U.S. Department of Energy
National Transportation Program





Von Mises Stress in Outer Shell for Outer Shell Thickness = 1.54 inches

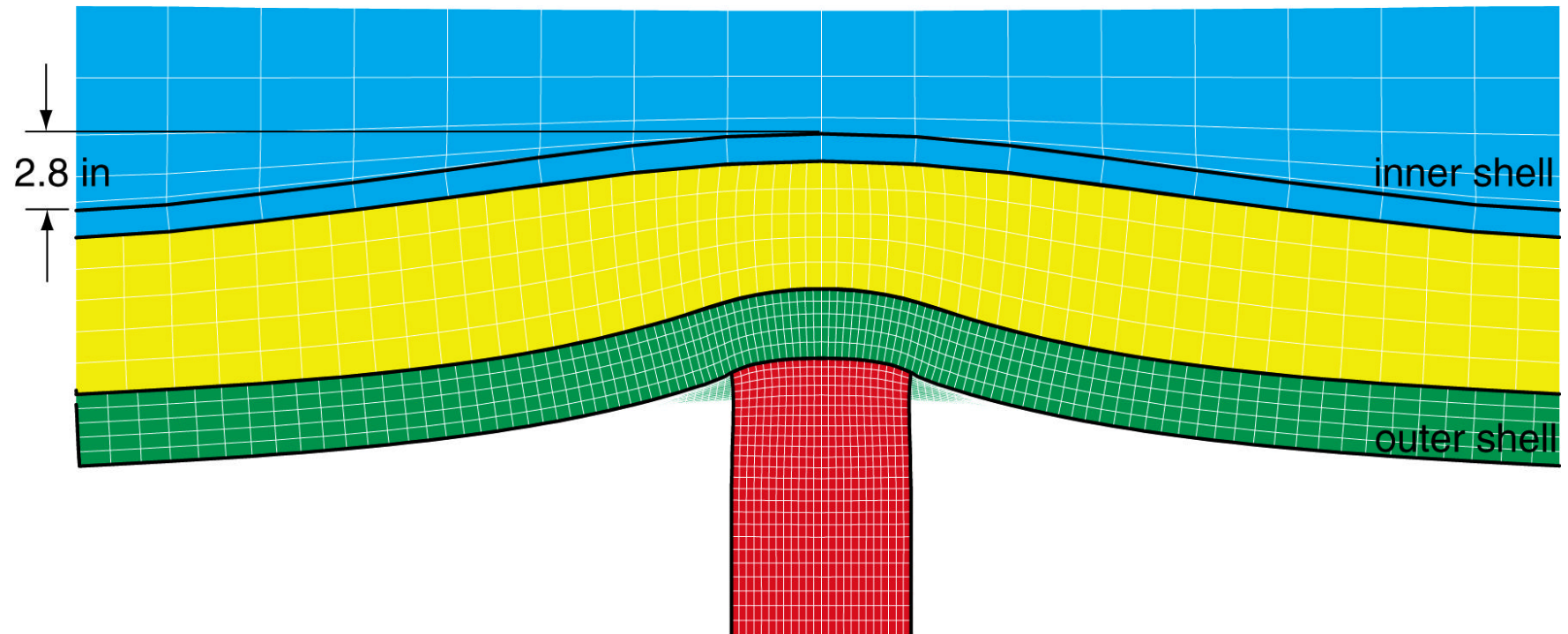


U.S. Department of Energy
National Transportation Program





Deflection of Interior Containment Boundary for Outer Shell Thickness = 2.6 inches

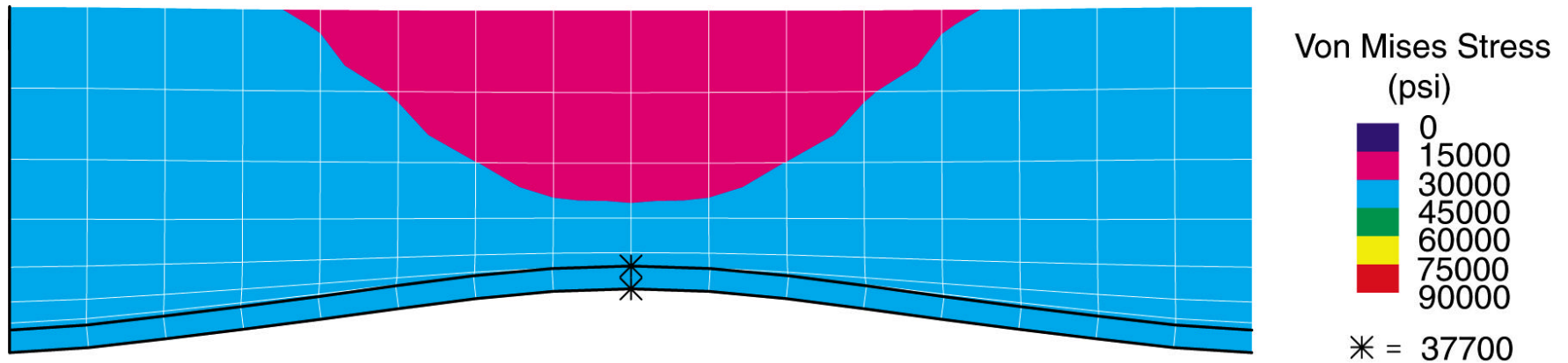


U.S. Department of Energy
National Transportation Program





Von Mises Stress in Inner Shell for Outer Shell Thickness = 2.6 inches

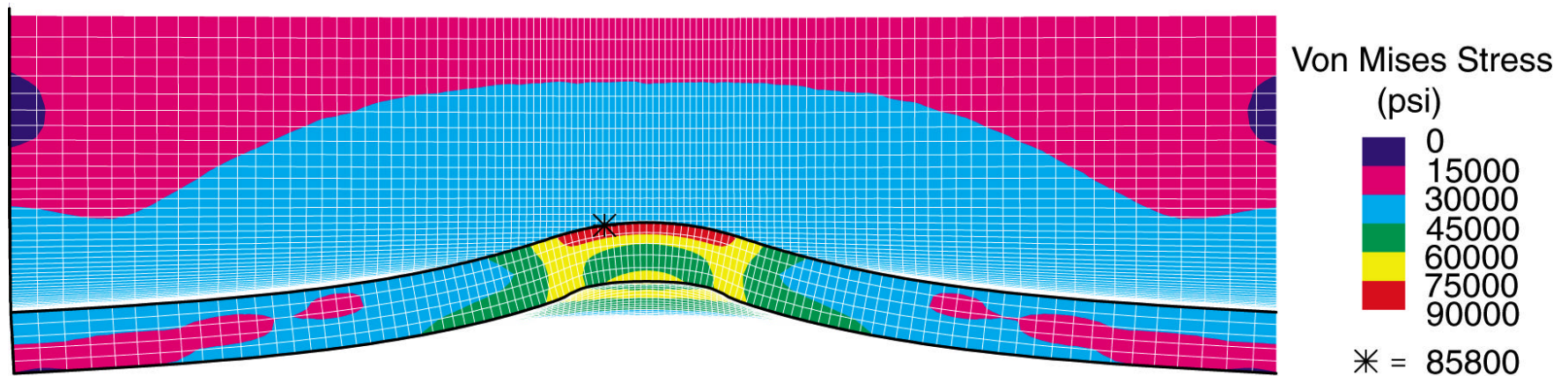


U.S. Department of Energy
National Transportation Program





Von Mises Stress in Outer Shell for Outer Shell Thickness = 2.6 inches



U.S. Department of Energy
National Transportation Program





Discussion of Results

- **NUPACK code gives a formula for outer shell thickness, but not for containment boundary.**
- **Code Case N-626 gives allowable stresses for containment boundary, but not outer shell.**
- **The outer shell thickness suggested by the NUPACK code has outer shell stress higher than Code Case N-626 allowable.**



U.S. Department of Energy
National Transportation Program





Material Data

- **The material data in the ASME Boiler and Pressure Vessel Code was not developed for non-linear dynamic analyses.**
- **The acceptance criteria from Code Case N-626 uses only a very small portion of the energy absorbing capacity of stainless steel.**

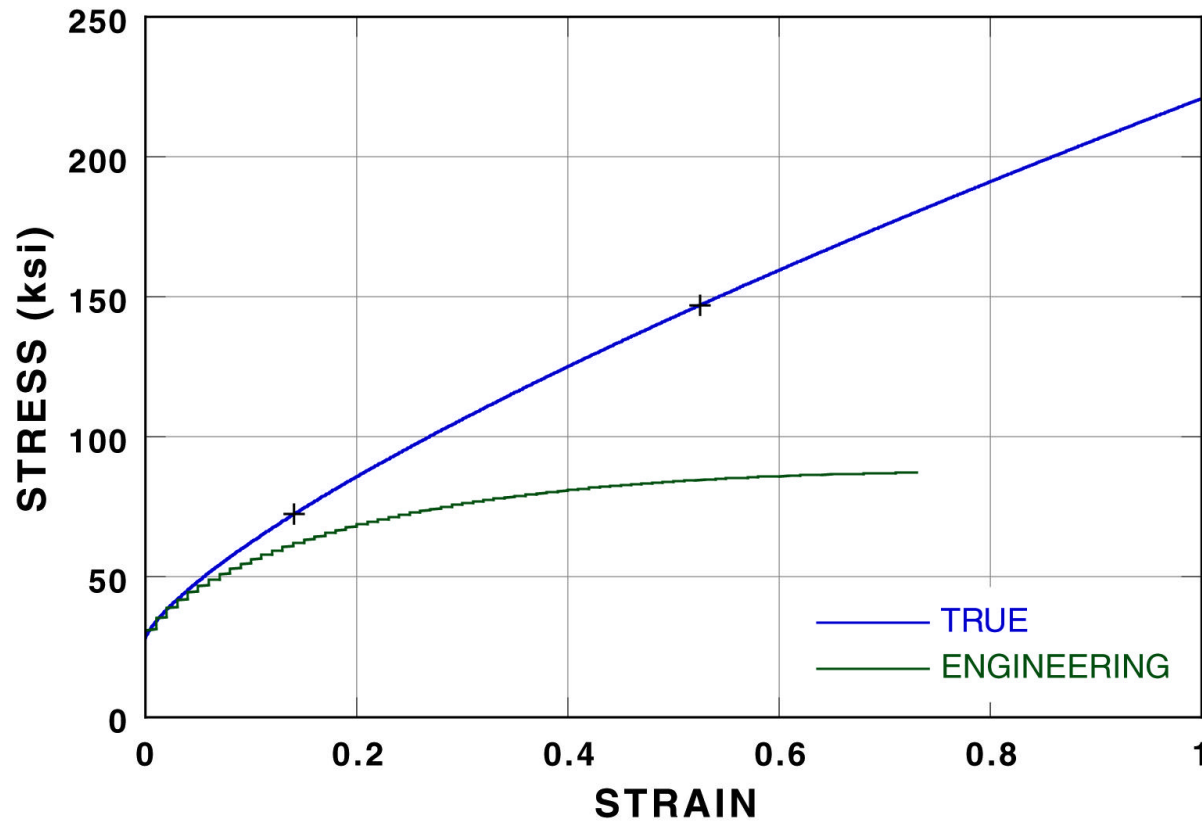


U.S. Department of Energy
National Transportation Program





True Stress vs. True Strain Curve for 304L Stainless Steel



U.S. Department of Energy
National Transportation Program





Summary and Recommendations

- **Inelastic analysis provides an accurate prediction of the behavior of casks to hypothetical impact and puncture events.**
- **Puncture can be prevented using thinner outer shells than required by the NUPACK code.**
- **Maximum stresses in the containment boundary are less than that required by Code Case N-626.**



U.S. Department of Energy
National Transportation Program

